



US006504972B2

(12) **United States Patent**
Watanabe(10) **Patent No.:** **US 6,504,972 B2**
(45) **Date of Patent:** **Jan. 7, 2003**(54) **OPTICAL FIBER COMMUNICATION
SYSTEM USING OPTICAL PHASE
CONJUGATION AS WELL AS APPARATUS
APPLICABLE TO THE SYSTEM AND
METHOD OF PRODUCING THE SAME**

FOREIGN PATENT DOCUMENTS

JP	60-173504	9/1985
JP	62-159104	7/1987
JP	5-323396	12/1993
JP	7-301830	11/1995
JP	8-95106	4/1996

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OTHER PUBLICATIONS

(*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

Inoue, "Suppression technique for fiber four-wave mixing using optical multi-demultiplexers and a delay line", Mar. 1993, Journal of lightwave technology, vol. 11, No. 33, pp. 455-461.*

(21) **Appl. No.:** 09/873,360(22) **Filed:** Jun. 5, 2001

(List continued on next page.)

(65) **Prior Publication Data**

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Primary Examiner—Ellen E. Kim(74) *Attorney, Agent, or Firm*—Staas & Halsey LLP

Related U.S. Application Data

(63) Continuation of application No. 09/051,788, filed on Apr. 20, 1998, which is a continuation of application No. PCT/JP97/02926, filed on Aug. 22, 1997, now Pat. No. 6,307,984.

(30) **Foreign Application Priority Data**

Aug. 22, 1996 (JP) 08-221274

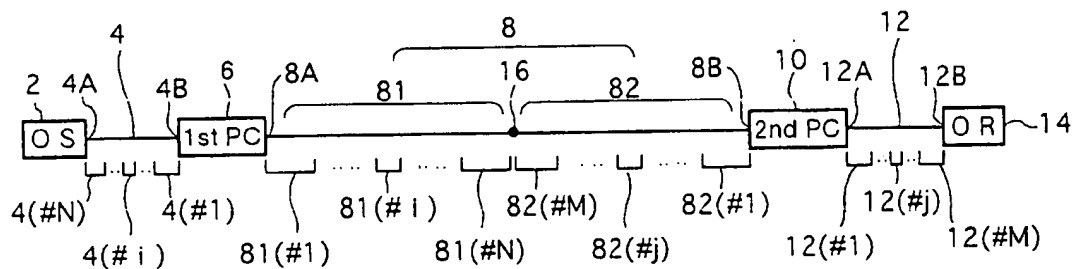
(51) **Int. Cl.⁷** G02B 6/28(52) **U.S. Cl.** 385/24; 385/15; 385/31;
359/326(58) **Field of Search** 385/24, 122, 326,
385/15, 31; 359/174, 337, 332, 336, 326(56) **References Cited**

U.S. PATENT DOCUMENTS

5,365,362 A	11/1994	Gnauck et al.	359/174
5,386,314 A	1/1995	Jopson	359/326
5,532,868 A	7/1996	Gnauck et al.	359/332
5,550,671 A	8/1996	Simpson et al.	359/337
5,568,583 A	10/1996	Akasaka et al.	385/123

(57) **ABSTRACT**

An optical fiber communication system according to the present invention has, for example, first and second phase conjugators. The first phase conjugator converts a signal beam from a first optical fiber into a first phase conjugate beam. The first phase conjugate beam is supplied to the second phase conjugator by a second optical fiber. The second phase conjugator converts the first phase conjugate beam into a second phase conjugate beam. The second phase conjugate beam is transmitted by a third optical fiber. The second optical fiber is composed of a first portion located between the first phase conjugator and a system midpoint and a second portion located between the system midpoint and the second phase conjugator. The total dispersion of the first optical fiber substantially coincides with the total dispersion of the first portion, and the total dispersion of the second portion substantially coincides with the total dispersion of the third optical fiber. By the construction, waveform distortion by chromatic dispersion or nonlinearity is compensated for.

8 Claims, 25 Drawing Sheets

OTHER PUBLICATIONS

Hedekvist et al, "Impact of Spectral inverter fiber length on four wave mixing efficiency and signal distortion", Sep. 1995, Journal of lightwave technology, vol. 13, No. 9, pp. 1815-1819.*

Kikuchi et al., "Design of highly efficient four-wave mixing devices using optical fibers", Aug. 1994, IEEE Photonics technology letters, vol. 6, No. 8, pp. 992-994.*

Inoue et al. "Wavelength conversion experiment using fiber four-wave mixing", Jan. 1992, IEEE Photonics technology letters, vol. 4, No. 1, pp. 69-72.*

S. Watanabe, M. Shirasaki, "Exact Compensation for Both Chromatic Dispersion and Kerr Effect in a Transmission Fiber Using Optical Phase Conjugation," Journal of Lightwave Technology, vol. 14, No. 3, Mar. 1996, pp. 243-248.

"Laser Study" (in Japanese), The Society of Laser Engineers (30 06 96), vol. 24, No. 6, pp. 649-655.

S. Watanabe, "Cancellation of Four-Wave Mixing in a Single-Mode Fiber by Midway Optical Phase Conjugation," Optics Letters, vol. 19, No. 17, Sep. 1, 1994, pp. 1308-1310.

* cited by examiner

FIG. 1

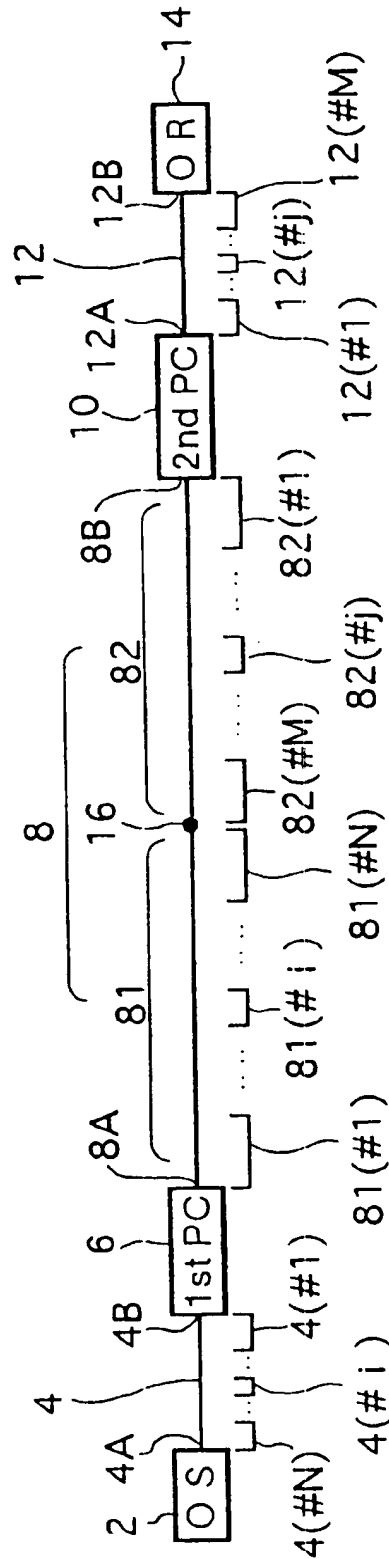


FIG. 2

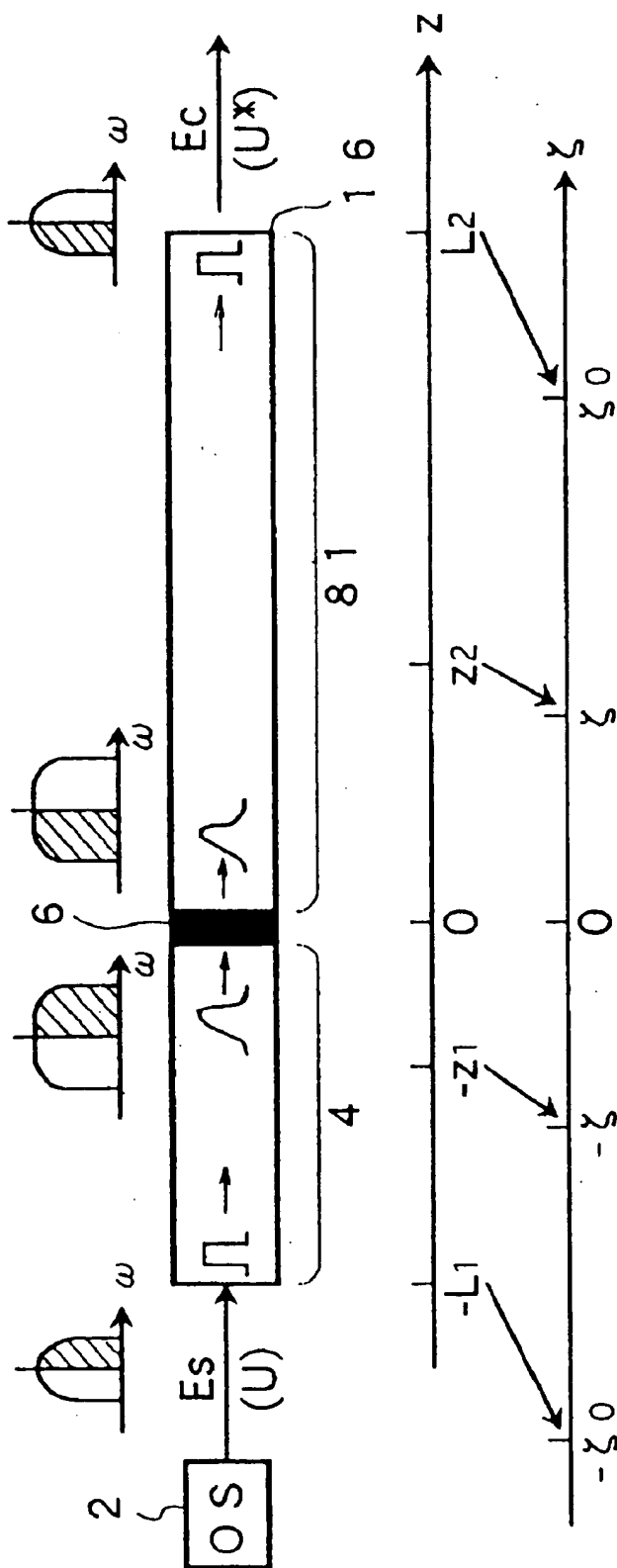


FIG. 3

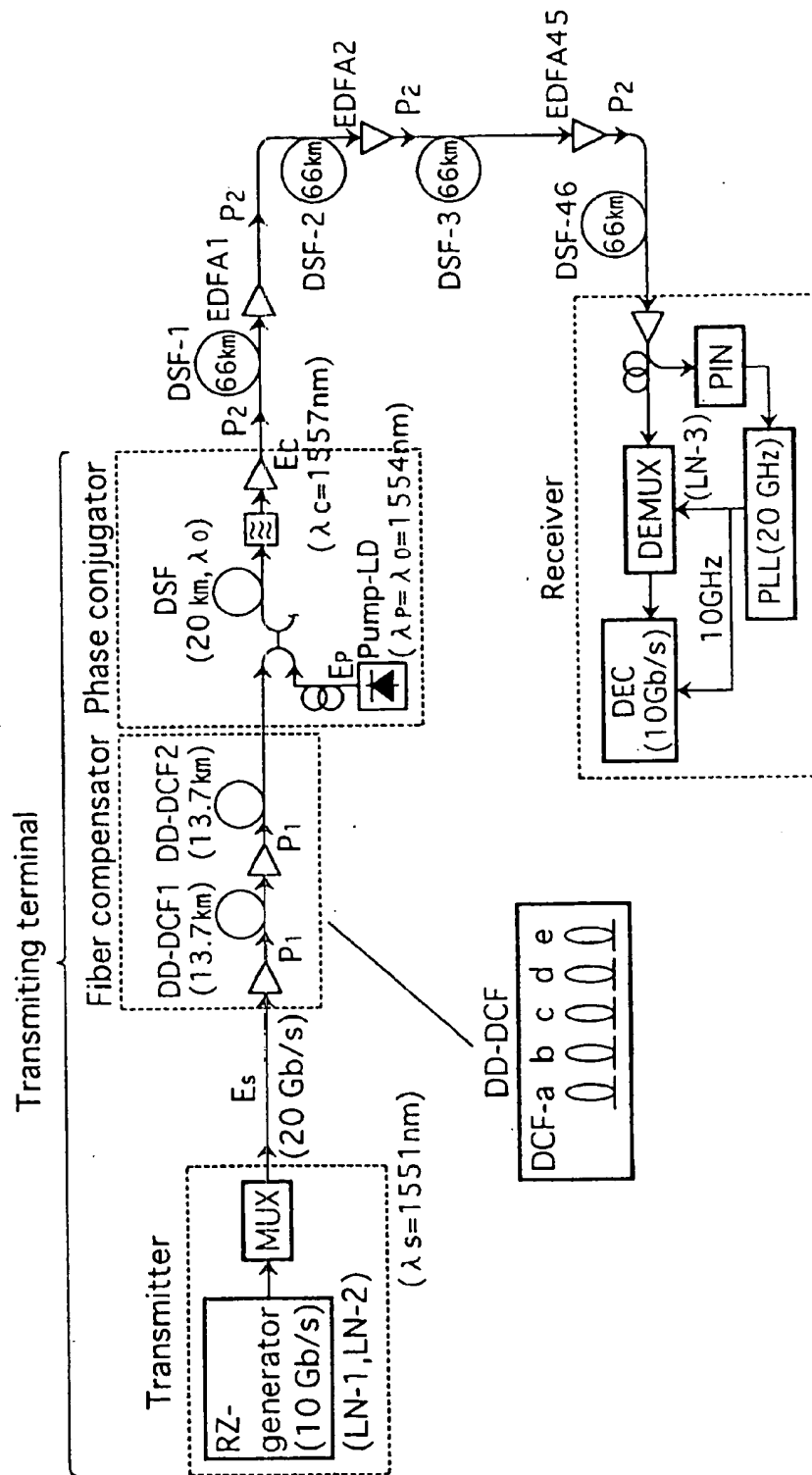


FIG. 4

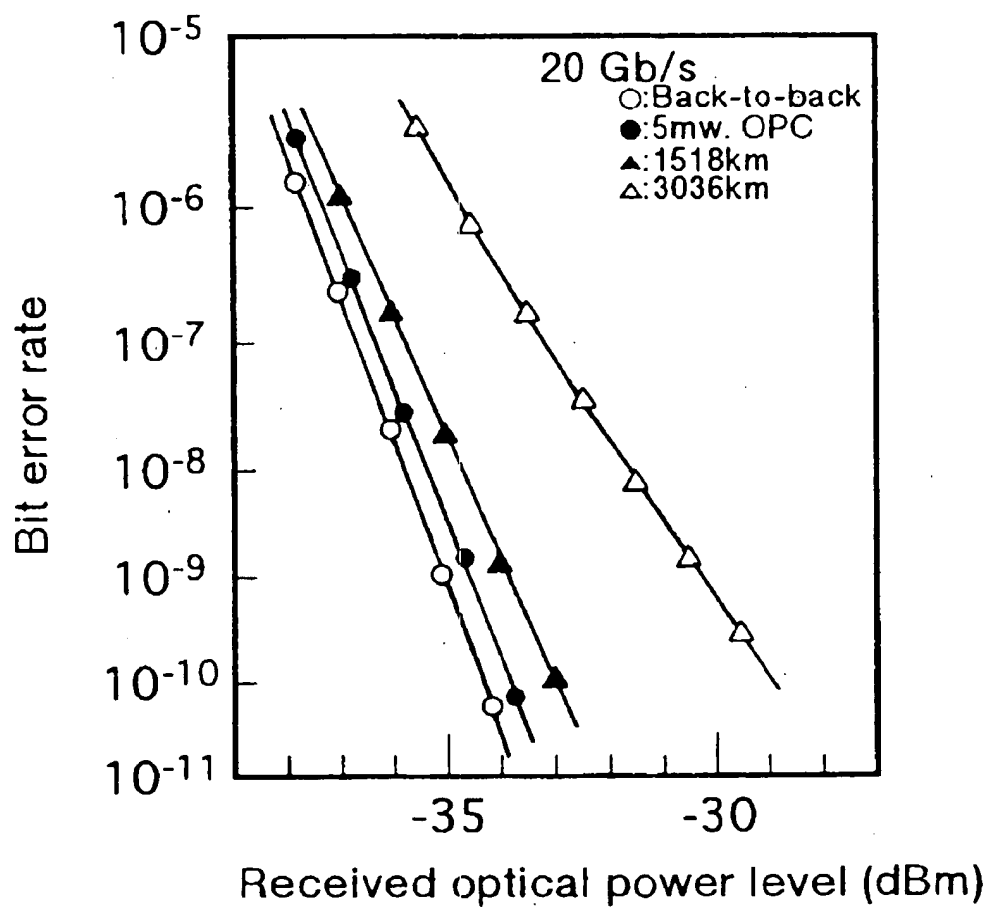


FIG. 5A

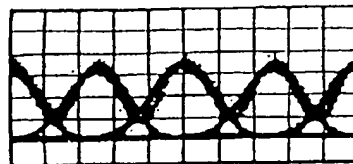


FIG. 5B

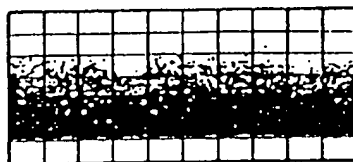


FIG. 5C



FIG. 5D



FIG. 5E

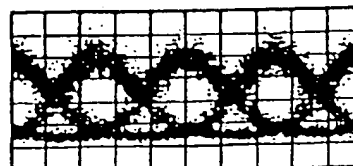


FIG. 6

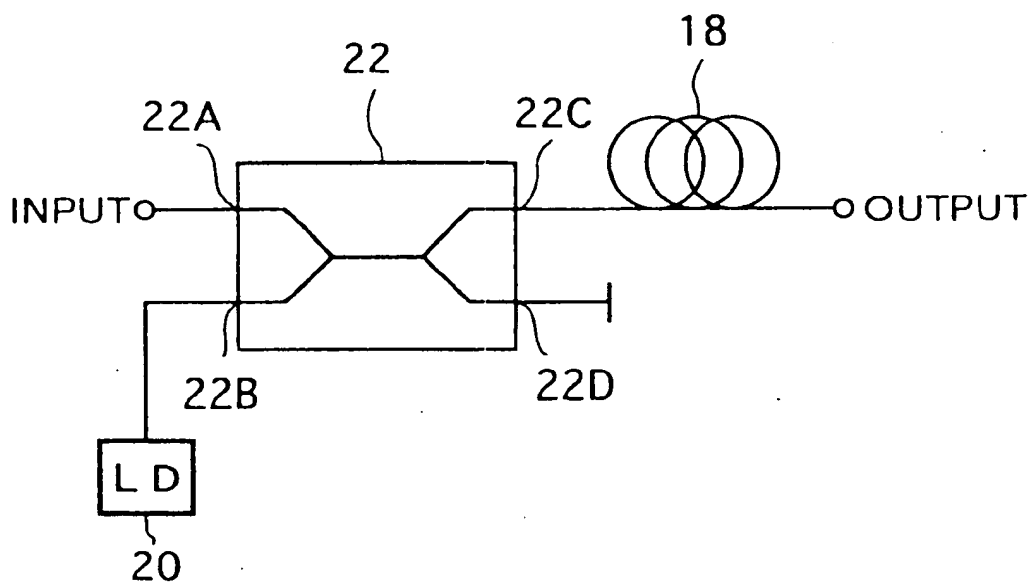


FIG. 7

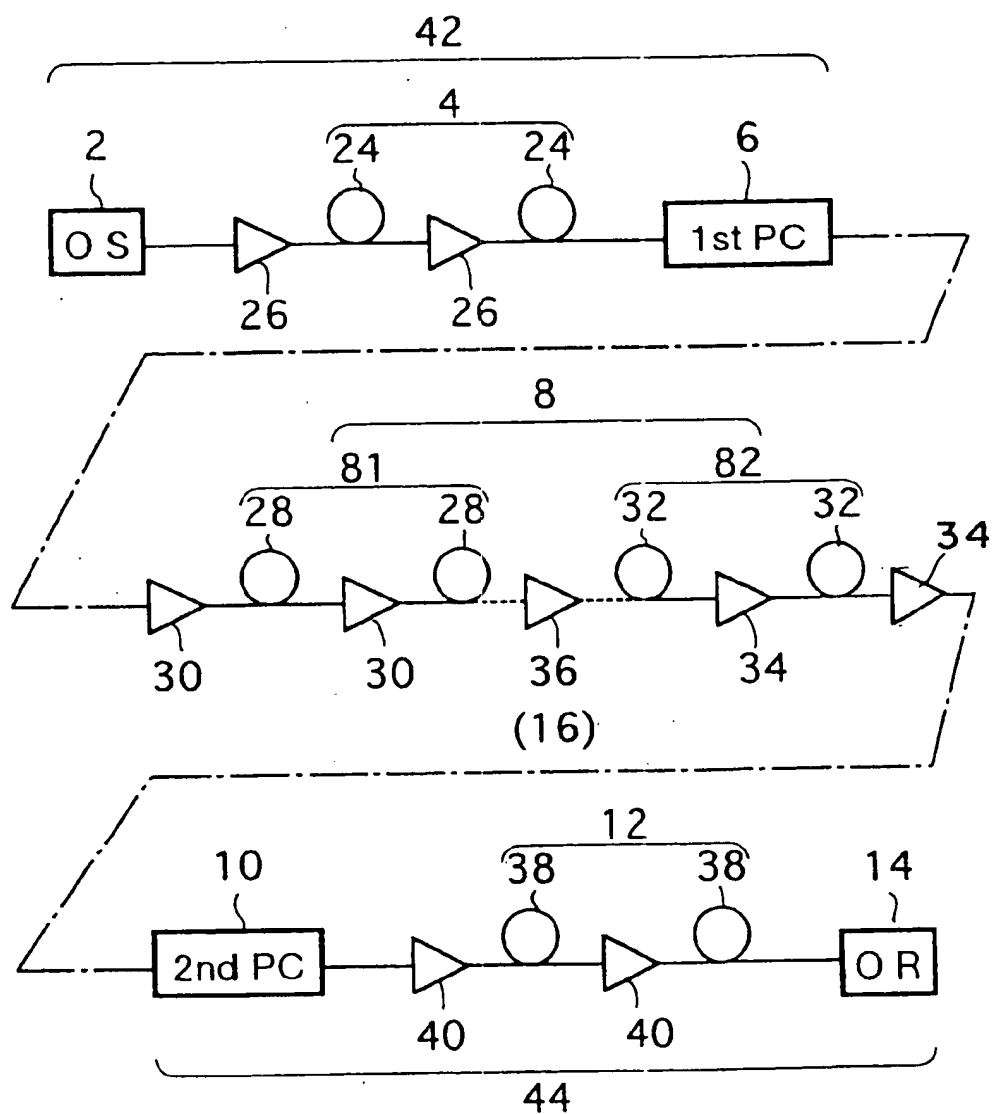


FIG. 8

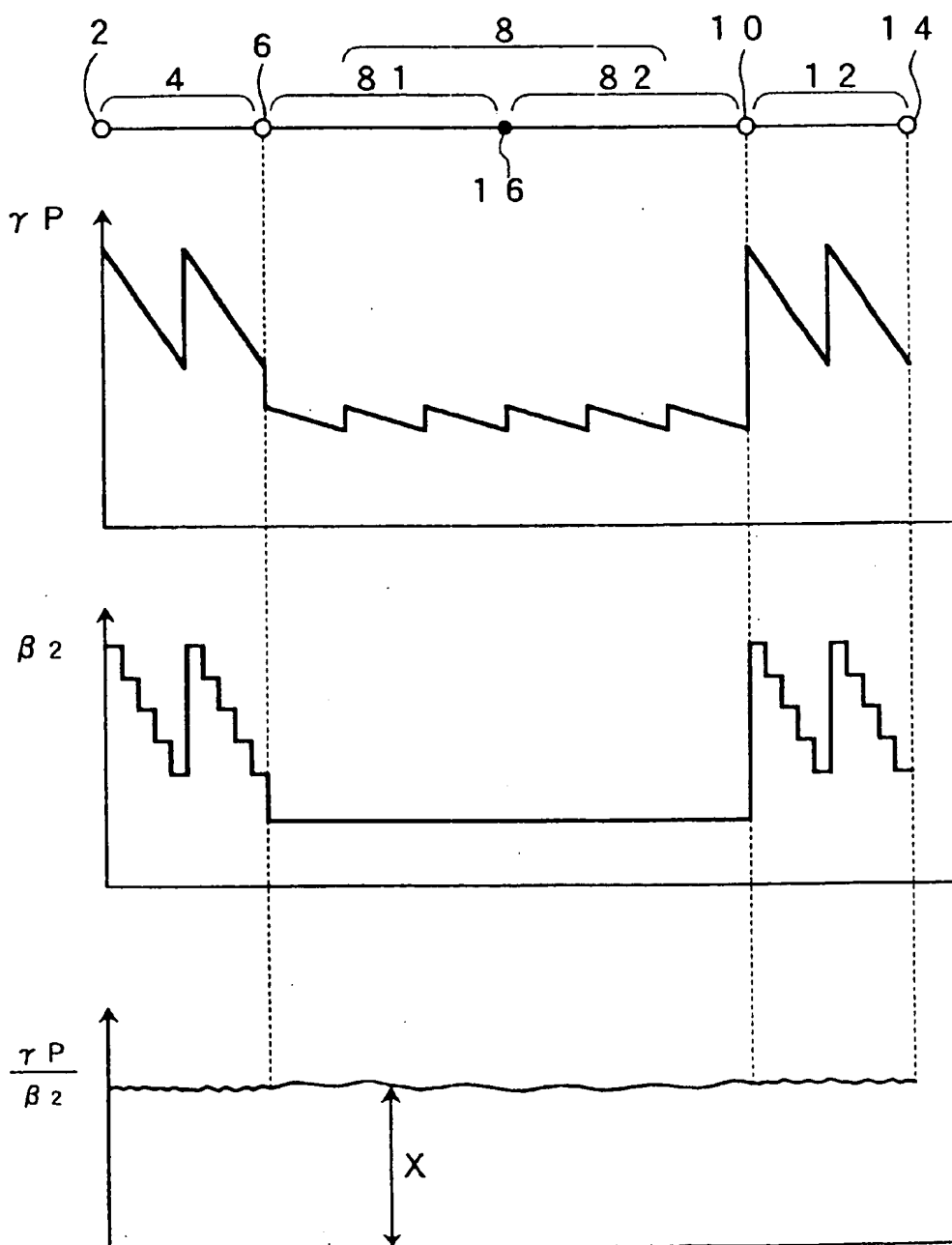


FIG. 9

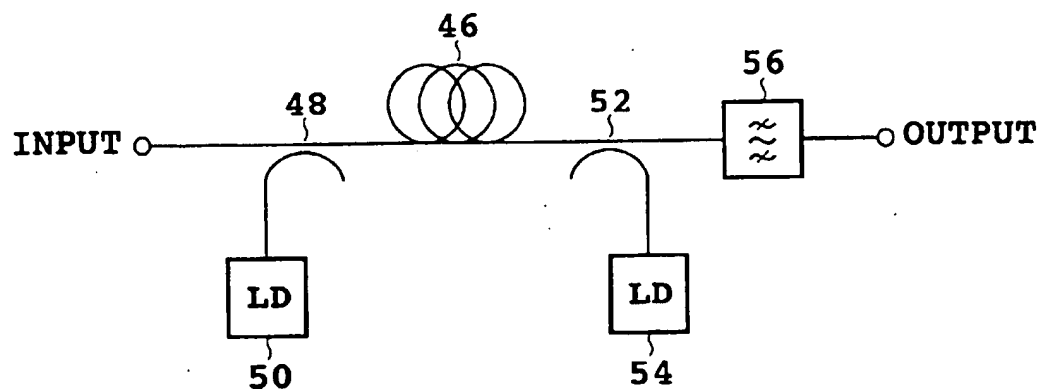


FIG. 10

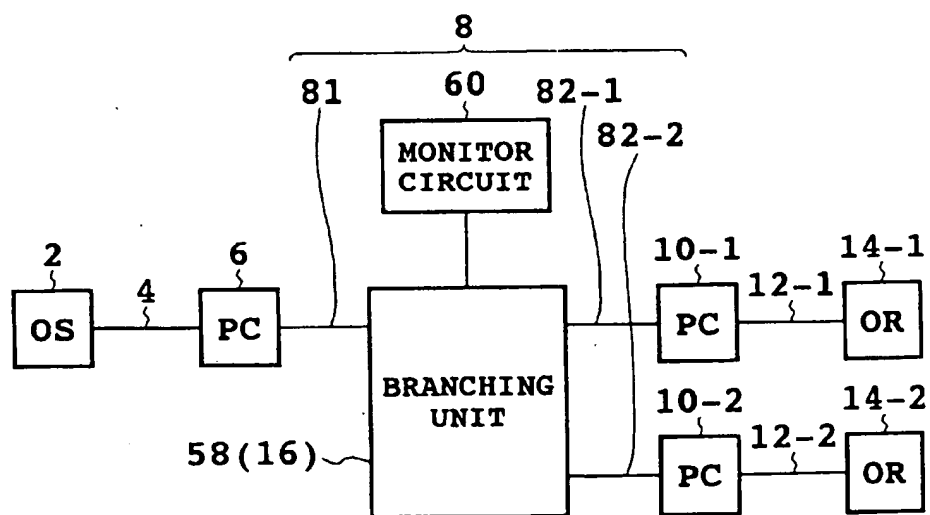


FIG. 11

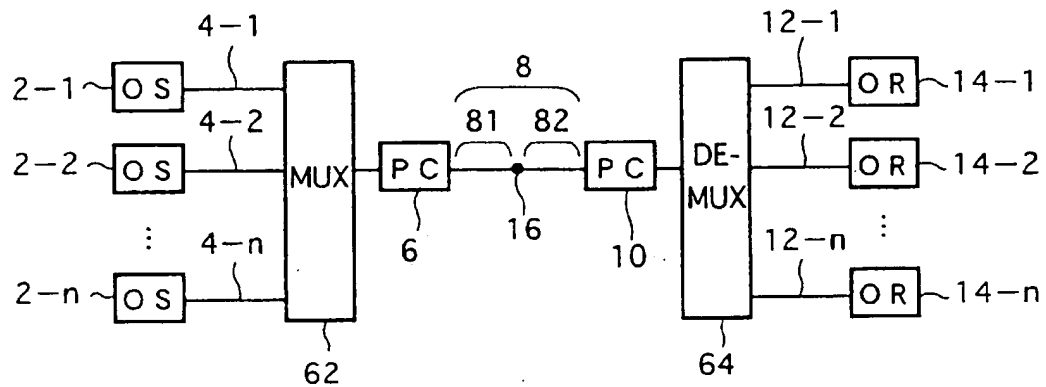


FIG. 12

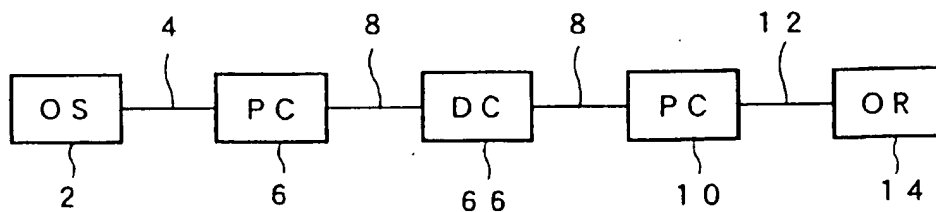


FIG. 13

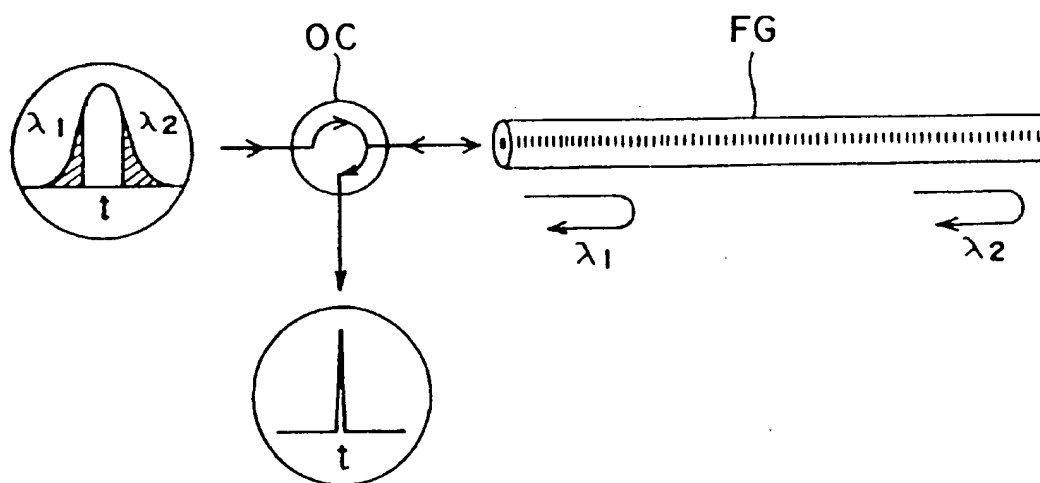


FIG. 14

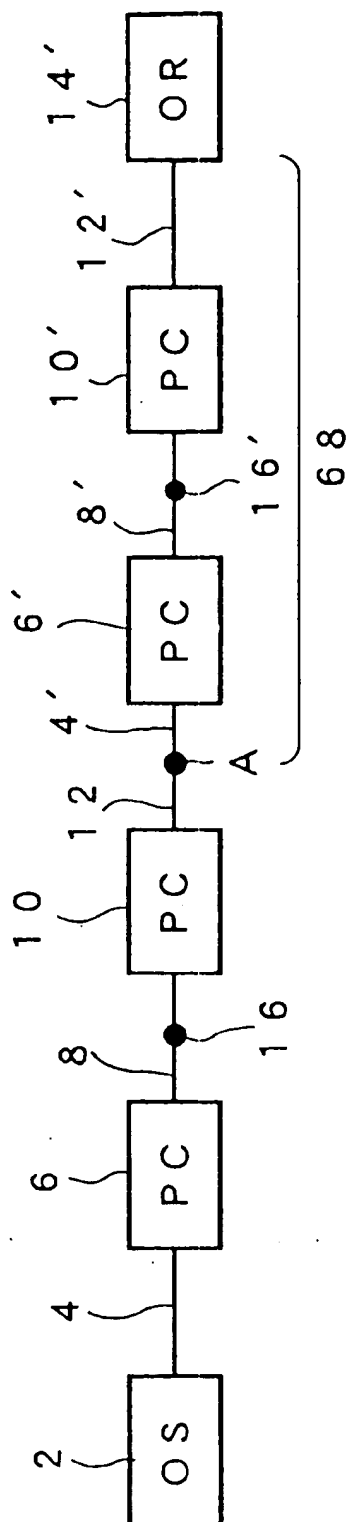


FIG. 15

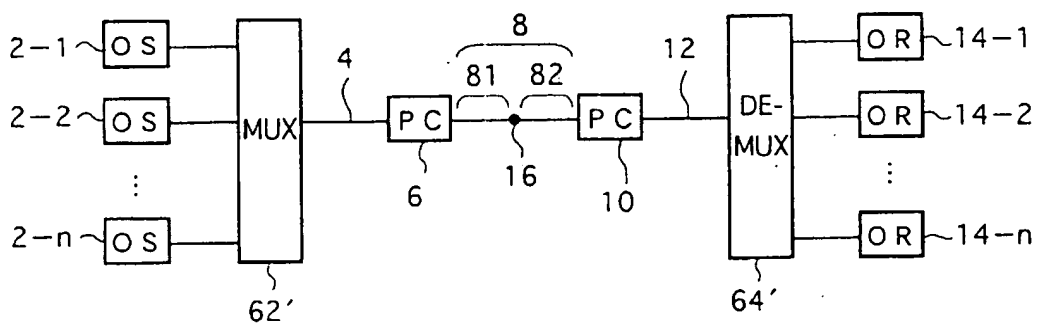


FIG. 16

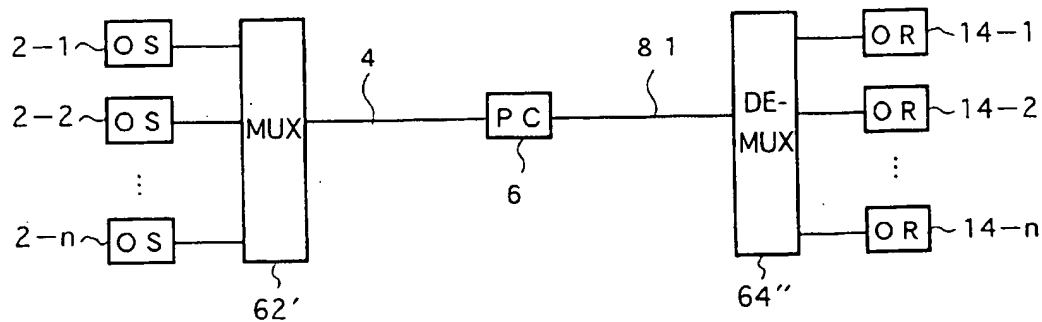


FIG. 17A

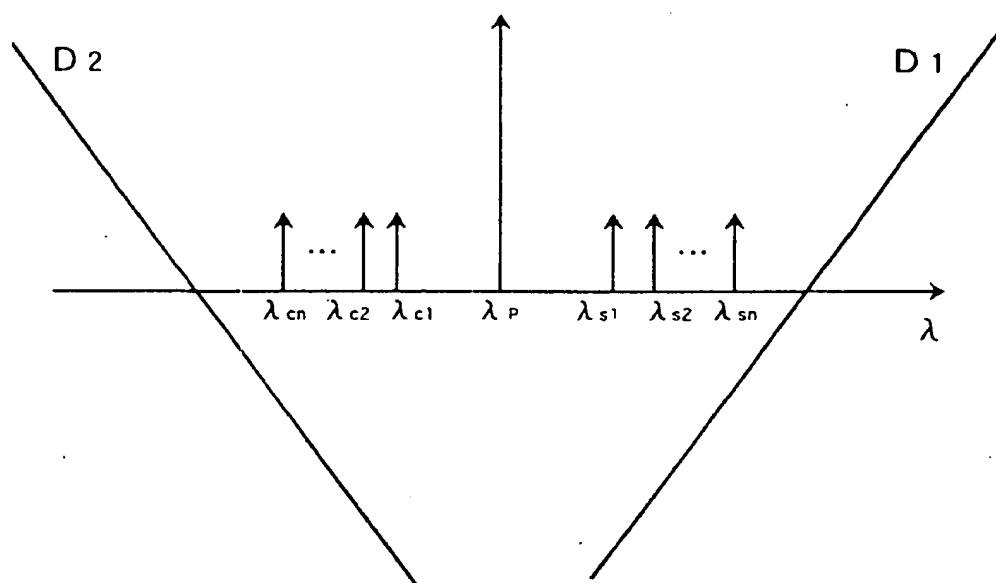


FIG. 17B

